ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia
Social and Behavioral Sciences
Procedia - Social and Behavioral Sciences 30 (2011) 1481 – 1487

WCPCG-2011

Cognitive consequences of segmentation and modality methods in learning from instructional animations

Hamidreza Hassanabadi [a,*], Effat Sadat Robatjazi [b], Azar Pakdaman Savoji [c]

[a] *Department of Educational Psychology, Trabiat Moallem University, Tehran, Iran*
[b] *M.A. in Educational Psychology, Saveh Branch, Islamic Azad University, Saveh, Iran*
[c] *Department of Educational Psychology, Saveh Branch, Islamic Azad University, Saveh, Iran*

Abstract

This study was to investigate whether a chunking of animations about the lightning system can increase learning by designing it with sensitivity to the capacity limitations of working memory. A total of 96 girl students of junior high schools, divided into four groups, participated in the study. These groups learned from texts and animations in a 2 × 2 design with the factors modality (narration vs. on- screen text) and segmentation type (system-control vs. learner-control) and saw the process of lightening formation through 16 slides. The system-controlled segments group had 3 second pause between each slide and slides showed automatically, but learner-controlled segments group had chose to see the next slide by press play button. Retention and transfer of the learning material and cognitive load were assessed. The results showed that narration group outperformed on- screen text group in retention. The learner- controlled group outperformed system- controlled group in retention and reported less cognitive load. There was no interaction between modality and segmentation type. The chunking effect in multimedia learning is higher when the learner can control the pace of presentation.

Keywords: Instructional Animations, Working Memory, Segmentation, Cognitive Load, Multimedia Learning;

1. Introduction

Nowadays, dynamic visualisations, such as computer animations, were increasingly used for teaching students about the chains of events in dynamic systems (Lowe, 2004). This is probably done because animations are seen as attractive for students (Chandler, 2009; Perez & White, 1985) and are usually expected to be more effective than static visuals because students can perceive changes over time rather than having to mentally infer them (Lowe, 1999). However, although, animations seem theoretically and intuitively a better instructional format for representing change over time, but the several empirical studies (e.g., Mayer, Hegarty, Mayer, & Campbell, 2005; Höffler & Leutner, 2007; Tversky, Morrison, & Betrancourt, 2002) showed that those can hinder rather than improve learning.

A potential explanation for the lack of learning benefits when studying from animations is that their processing requires high levels of mental abstraction and synthesis of the procedures modelled, which can overload students' cognitive capacity, especially when students are novices in a domain and lack appropriate domain knowledge to guide their attention (Sweller, 2004). In addition, animations may impose greater cognitive processing demands than

* Hamidreza Hassanabadi. Tel: +98-21- 88848938; fax: +98-21- 82883617.
E-mail address: hrhassanabadi @ gmail.com.

doi:10.1016/j.sbspro.2011.10.287

static visuals because information is frequently transient if critical objects and their relations disappear during the animation (Hasler, Kersten, & Sweller, 2007). When viewing transient animations, learners not only need to integrate new information with knowledge they have stored in long-term memory but also with what they have been presented in earlier parts of the animations because previously presented information does not remain visually available (Moreno & Mayer, 2007). Mentally integrating the currently presented visual information of a transient animation with previous information may be difficult because of the temporal limitations of working memory. As a consequence, the animations put a high cognitive load on working memory of learners because of high pace of presentation and successive and transient information elements that almost impaired learning.

The problem seems to be complex when animations presented with text, because these instructional formats require learners to mentally integrate several independent sources of information those are unintelligible in isolation. This process of attending to two distinct sources of information may impose a high cognitive load, exceeding limited capacity of working memory, referred to as the visual split-attention effect (Sweller, van Merriënboer, & Paas, 1998). To understand a conventional separate text and animation format, the learner must hold small segments of text in working memory while searching for the matching diagrammatic graphical entity, with this ongoing process continuing until all the information is rendered intelligible (Kalyuga, Chandler, & Sweller, 1999). However, the process of mental integration is not directly related to learning; it is essentially a preliminary activity to learning (Sweller et al., 1998). The question arises whether the cognitive load imposed by high pace, successive and transient instructional animations can be ameliorated by an appropriate instructional design.

To improve the effectiveness of animations by taking cognitive load into account, several design principle have been proposed (for reviews, see Moreno & Mayer, 2007; Wouters, Tabbers, & Paas, 2008). The most principles include text modality, that is, presenting graphics be accompanied by concurrent narration rather than concurrent on-screen text (Mayer, 2001, 2005) and segmentation, that is, showing animations into smaller pieces or parts (e.g., Hasler et al., 2007; Mayer & Chandler, 2001; Moreno, 2007). According to the modality effect, better learning will occur when words are presented as narration rather than as on-screen text (Mayer, 2001). Several research also showed that learner learn more from animation and narration compare with animation and on-screen text in multimedia environments (Ginns, 2005; Mayer, 2001) and observed in various measures: less mental effort with narration (Tabbers, 2002), less time in solving tasks (Jeung, Chandler & Sweller, 1997; Mousavi, Low & Sweller, 1995), and higher scores on various assignments of retention and transfer (Hassanabadi, 1387/ 2008; Kalyuga et al., 1999; Mayer & Moreno, 1998; Moreno & Mayer, 1999; Mousavi et al., 1995). Cognitive Theories (Mayer, 2001, 2005; Sweller, 2005) accounting for this modality effect rely on a common explanation. They, With reference to Baddeley's (1992) working memory model, assumed capacity-limited processing channels for visual and auditory information. If on-screen text is added to an animation, both information sources must be processed by the visual processing channel. Presenting narration is assumed to increase the effective working memory capacity by off-loading the visual channel while occupying the previously unused capacity of the auditory channel.

The second and better instructional technique to overcome the problems associated with high extraneous load due to processing transient information, it has been suggested that the instructions are divided into smaller, meaningful segments (Mayer & Moreno, 2003; Moreno & Mayer, 2007). Segmentation allows learners to view a presentation in discrete segments rather than as one continuous presentation. Mayer and Chandler (2001) by putting a button labeled CONTINUE allowed learner to start the next segment by clicking on it. Results showed students who received the segmented presentation performed better on subsequent tests of problem solving transfer than did students who received continues presentation. Also, Moreno (2007) showed the group who received the segmented presentation performed better on subsequent retention and transfer tests and had less mental effort compare to the group who received continue presentation. However, research on segmentation in multimedia instruction has provided inconsistent results. Whereas some authors have obtained positive effects for segmentation (Mayer & Chandler, 2001; Mayer, Dow, & Mayer, 2003), others found limitations of the segmentation effects that being beneficial for learning (Moreno & Valdez, 2005; Tabbers, Martens, & van Merrienboer, 2004).

Using segmentation in multimedia learning is depended on the pusses between segments. These pusses can be inherent in system, by automatically pausing between logical segments or controlled by learner (Mayer & Moreno, 2003). Evidence for first situation was found in a study where students who viewed segments of a narrated animation depicting the process of lightning formation outperformed those presented with the whole narrated animation on retention, visual–verbal matching and transfer tests (Mayer, Moreno, Boire, & Vagge, 1999) and evidence for second situation was findings by Mayer & Chandler (2001). By the pause the learner selects relevant words and pictures from one segment of the presentation, after the next segment begins. When the narrated animation is presented continuously-without time breaks between segments- the learner can select words and images from the first segment, but before the learner is able to complete the additional processes of organizing and integration, the next segment is presented, which demands the learner's attention for selecting words and images. This situation leads to cognitive overload in which available cognitive capacity is not sufficient to meet the required processing demands. The pauses between animation presentations help learner to process information without extra cognitive load and select next information and organize and coherent selected words and images (Clark & Mayer, 2008; Florax & Ploetzner, 2010; Hasler et al., 2007; Mayer & Chandler, 2001). As a consequence, Mayer and Moreno (2003) and Betancourt (2005) discussed that more research is needed to determine the separate effects of segmenting and interactivity, such as comparing how students learn from multimedia presentations that contain built-in or learner-controlled breaks after each segment.

The aim of this study was to investigate that whether segmenting an animation into smaller portions would decrease cognitive load and promote learning in teenage learners who worked on computers in either system-controlled or learner-controlled groups in a multimedia learning environment. The only difference between these two groups was using "play" button in learner- controlled group. In other words, both groups receive the first segment, after a 3 second pause, the next segment will start for system- controlled group, but for the learner-controlled group "play" button appears on screen and learner can select the next segment in her own pace. So, the learner has enough time and capacity to organize and integrate the selected words and images. Then the learner is ready for the next segment and so on. The pause between two segments can be short or long and this is a simple interaction with system in learner- controlled group. The difference between this study compare with previous studies is comparing system- controlled and learner- controlled groups simultaneously in learning segmented presentation with pause. However, research on effect of the control of instruction pace (e.g., Tabbers, 2002) has shown that principles that have a positive effect on performance for students at system-controlled instruction might have no, or even a negative, effect on performance for students at learner- controlled instruction. Thus, second goal of this research was to examine whether type of segmentation moderate text modality of animations on cognitive load and learning. It is challenging to know if learner interaction with system by control of pace has improved learning in one hand, and has interaction with modality effect in the other hand.

2. Method

2.1. Participants and design

The participants were 96 third grade girl students of junior high schools who selected by clustered sampling from different regions of Isfehan. At the first step 2 reigns were selected randomly and then 10 schools from each reign were selected randomly, and these 96 students were selected randomly from these schools. The interaction effect of segmentation type (system-controlled vs. learner- controlled) and text modality (narration vs. on-screen text) were tested in a 2×2 completely randomized factorial design. There were 24 students who assigned randomly in each group. All participants received individually the content of lightning formation. During the study 16 individuals (4 participants in each group) withdraw from the study for reasons such as lack of partnership or no responding with tests.

2.2. Materials and Apparatus

For each participant, the paper-and-pencil materials consisted of a prior knowledge questionnaire, a subjective cognitive load scale, a retention test and a transfer test. Prior knowledge of participants about meteorology was assessed with a 6- item checklist and a 7-point self-rating scale (1 as very little and 7 as very much) about lightening formation used by Moreno and Mayer (1999). Cognitive load scale was used to asses the subjectivity difficulty and invested mental effort during learning. The participants were asked (1) how difficult was it to learn about lightening formation with the computer program? (with 1 as extremely easy and 7 as extremely difficult), and (2) How much effort did you have to invest to learn about lightening formation with the computer program? (with 1 as very little amount of effort and 7 as a very much amount of effort). Retention test consist of a recall question for assessing the memorizing and maintenance the learning materials and transfer test consist of four transfer questions for assessing problem solving in new situations by individuals.

The computerized materials were four computer programs for multimedia presentations on how the lightning process works, with each consisting of a sequence of 16 frames describing the causal chain of events leading to the process of lightning formation. The 16 frames represented these events either in on-screen text with animation or narration with animation formats which was either system-controlled or learner-controlled. The multimedia presentations were developed using Flash MX and four 17-in computer systems were used for experiments that two of them had Sony headphones for listening to the narrations.

2.3. Procedure

Participants were assigned randomly in four experimental groups: Learner-controlled On-screen text presentation (LO), Learner- controlled Narration presentation (LN), System- controlled On-screen text presentation (SO), and System- controlled Narration presentation (SN) and received the instructions individually. Also, they were individually tested in a session. The experiment held in 30 sessions and each session was 45 minutes. In each session learner- controlled group or system-paced group were tested. Four participants were tested per session. Each participant was randomly seated in front of one computer. In each session two individuals received narration animation and two received on-screen text animation. In pre instruction stage, the purpose of study and brief information about work with computers was presented and participants answered to prior knowledge questionnaire without time limitation. After completing the questionnaire, the experimenter indicated that the computer would show a presentation of how the process of lightning works and that, when the program ended, participants would be questioned to assess how much they had learned. The participants could not see each other during the experiment. Once the presentation was finished, students were given cognitive load scale during the instruction for assessing cognitive load to complete at their own pace. Then 6 min to answer retention test and assessing cognitive load and 3 min to answer each of the four problems solving sheets of the transfer test and assessing its cognitive load.

Prior knowledge questionnaire and cognitive load scale were objectively marked by the researcher. To correct retention and transfer tests, we asked two teachers who had no information about the experiment to mark the tests individually using the same procedure as in Hassanabadi (1387/2008). A retention score was computed by counting the number of major idea units (out of 19 possible) that the participant produced on the retention test. A transfer score was computed for each participant by tallying the number of acceptable answers across the four transfer problems. Questions were open ended, so participants could receive as many points per problem as the correct answers they gave. The correlation between two scorers was .86 in retention and .62 in transfer tests. The average scoring was taken as the retention and transfer scores.

3. Results

We conducted analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) to determine if the treatment groups differed on the dependent measures. Data were screened for extreme or missing values and statistical assumptions were evaluated using graphical plots and statistical tests. No significant departures from the assumptions of normality and homogeneity of variances or of covariance matrix were noted. Alpha was set at .05 for all statistical tests. Table 1 shows the mean scores and standard deviations for four groups on measures of retention, transfer, difficulty rating and mental effort.

Table 1. Mean scores and standard deviations for four groups on retention, transfer, difficulty and mental effort

Group	retention		transfer		difficulty		Mental effort	
	M	SD	M	SD	M	SD	M	SD
LO	3.80	2.35	.92	.84	2.15	1.13	3.90	1.61
LN	5.02	2.06	1.20	.96	2.75	1.41	4.15	2.11
SO	2.75	1.75	.75	.55	3.30	1.65	3.80	2.01
SN	3.85	2.50	1.10	1.31	3.35	1.34	4.10	1.48

Two- way ANOVAs conducted on retention and transfer scores with modality (narration and text) and segmentation type (learner-controlled and system- controlled) variables. The first ANOVA revealed significant effect on retention by modality F (1, 76) = 5.52, MSE = 4.79; p = .021; partial η^2 = .07. Mean retention scores showed that narration group (M = 4.44, SD = 2.34) had higher scores than text group (M = 3.29, SD = 2.11). Also, there was a significant effect on retention by segmentation type, F (1, 76) = 5.05, MSE = 4.79; p = .027; partial η^2 = .06. Mean scores showed that learner- controlled group (M = 4.41, SD = 2.26) had higher scores than system-controlled group (M = 3.31, SD = 2.20). There was no significant interaction effect between text modality and segmentation type. The second ANOVA represented no significant effect on transfer scores in modality and segmentation type and their interaction.

We conducted multivariate analysis of variance (MANOVA) to determine if the treatment groups differed on the cognitive load. The MANOVA revealed significant differences among segmentation type groups, Wilkes's Λ = 0.87; F (2, 75) = 5.73; P = .005; partial η^2 = .13, but there was neither significant differences among modality groups Wilkes's Λ = 0.98; F (2, 75) = 0.54; P = 0.58, nor it interact with segmentation type; Wilkes's Λ = 0.99; F (2, 75) = 0.57; P = 0.57. At the next step, the follow F tests showed that there was a significant effect for only segmentation type on learning difficulty F (1, 76) = 7.81; MSE = 1.96; p = 0.007; partial η^2 = .09, but not on mental effort (F<1). Mean scores showed that learner- controlled group (M = 2.75, SD = 1.41) had less cognitive load during instruction than system- controlled group (M = 3.35, SD = 1.34).

4. Discussion

Our findings confirm again modality effect at the unique condition of this experiment include the use of segmented material in all experimental groups with teenagers participants. Also, it supported positive effects of learner- controlled instruction on reduce cognitive load and improve learning. In examining the first hypothesis that presentation of verbal information in narration form instead of on-screen text will improve learning, the results showed superiority of the narrative group to textual group only at retention test, but not at transfer test. This finding that narrative group had better performance at retention test than textual group is consistent with results of Hassanabadi (1387/2008), although other studies (e.g. Kalyuga, et al., 1999; Mayer, 1999; Mousavi, et al., 1995; Leahy, Chandler, & Sweller, 2003); showed this superiority in both retention and transfer tests.

We can explain these findings based on cognitive theory of multimedia learning and cognitive load theory. Within the context of cognitive theory of multimedia learning, there is three assumptions about how the mind works in multimedia learning: (1) *dual channel assumption*; humans possess separate information processing channels for verbal and visual material, (2) *limited capacity assumption*; there is only a limited amount of processing capacity available in the verbal and visual channels, and (3) *active processing assumption*; learning requires substantial cognitive processing in the verbal and visual channels (Mayer & Moreno, 2003). Based of these assumptions, when pictures and words are both presented in visual form, the eyes receive a lot of concurrent information, but only some of them can be selected for further processing in visual working memory. In this situation the visual channel overload, but verbal channel is off-loading. One solution to this problem is to present words as narration (Mayer, 2001; Sweller, et al., 1998). In this way, the words are processed in the verbal channel, whereas the animation is processed in the visual channel. Thus, the processing demands on the visual channel are reduced, so the learner is better able to select important aspects of animation for further processing. In short, the use of narrated animation represents a method for off-loading some of the processing demands from the visual channel to the verbal channel and this can improve performance that in our study had shown on retention test.

Another explanation of modality effect could be emotional effects of sounds. It seems that narration creates more emotion than on-screen text, and students usually prefer to listen to verbal explanation than reading such explanation. To explain that why this superiority has not found at transfer test, we can point at high difficulty coefficient of transfer tests and the traditional way of teaching in our schools that is more concerned with memorizing the facts than transfer the knowledge to new situations. Also, participants in this study were a teenagers group from junior school students (like participants at Hassanabadi, 1387/2008), inconsistent with prior studied that were college students.

To explain the second hypothesis of this study that segmented presentation in learner- controlled form will reduce cognitive load and increase learning, the results showed that learner- controlled group had less cognitive load compare with system- controlled group. This finding is consist with the results of Hasler et al. (2007) and Moreno (2007) who confirm the positive effects of learner- controlled learning on decreasing cognitive load in multimedia learning environment. We can explain this finding by the third assumption of Mayer's (2001, 2005) cognitive theory of multimedia learning about the active role of learner in processing information. The possibility of control the pace of presentation by reduction of information should be processed at working memory at any time, leads to reduce cognitive load and excessive load on working memory channels. Control of pace provides better opportunities for learners, in this situation they can spend more time on information sections to organize and integrate them; as in our study had shown that the learner- controlled group spend more time on study materials and had less cognitive load and more learning performance. Another explanation for the finding of second hypothesis of this study could be the sense of control. When participants are allowed to use the keyboard, they are given this feeling that they have control on their own learning (Hasler, et al., 2007); this feeling itself may provide more motivation and less cognitive load for learning.

The results of our experiment to explain the third hypothesis had shown no interaction effect between text modality and type of segmented presentation. This result is inconsistent with Chung (2006), Tabbers (2002) and Tabbers, et al. (2004) who showed interactive effect between modality and speed of presentation. According to these studies, it was expected if the learners can control the pace of presentation, on-screen text might be better than narration, and in system- controlled mode that learner had no control on presentation bimodal presentation will increase learning. To explain the inconsistency of our results with previous studies should note that the presentation time in our study was very short (less than 5 min), but in similar studies it was 70 min or more and also, the presentation mode in our study was segmented instead of continues.

In summary, the results obtained in this study provide empirical support for the validity and successful application of principles derived from cognitive theories (Mayer, 2005; Sweller, 2005) in the context of interactive multimedia learning. Furthermore, the findings of the experiment have a practical impact for instructional designers: Learner- control, in the form of pre-defined segments with PLAY button, should be integrated in instructional animation in order to improve learning. Based on this principle, various studies have concluded that animation is more effective when additional supporting strategies are introduced such as segmenting animations into smaller parts or providing learner-control animations (see Hasler, et al., 2007; Mayer & Chandler, 2001; Moreno, 2007; Schwan & Riempp, 2004). However, the length of the segments, as well as the speed of the entire animation may play a critical role and require further research. Furthermore, it is important to note that the implications of this study are limited because is conducted with a specific population (i.e. teenager students) and to teach a specific content domain (i.e. explanative content). Future research needs to show whether our findings can be generalised to other groups of learners as well as to different learning material.

References

Baddeley, A. D. (1992). Working memory. *Science, 255,* 556-559.

Betrancourt , M. (2005). The animation and interactivity principles in multimedia Learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 254–287). New York, NY: Cambridge University Press.

Chandler, P. (2009). Dynamic visualisations and hypermedia: Beyond the ‘‘Wow” factor. *Computers in Human Behavior, 25,* 389–392.

Chung, W. (2006). *The effects of presentation pace and modality on learning a multimedia science lesson.* Unpublished doctoral dissertation, The University of Texas, Austin.

Clark, R.C., & Mayer, R.E. (2008). *E-learning and the science of instruction proven guidelines for consumers and designers of multimedia learning,* second edition. John Wiley & Sons, Inc.

Florax, M., & ploetzner, R. (2010). What contributes to the split – attention effect? the role of text segmentation, picture labeling, and spatial proximity. *learning and instruction, 20,* 216- 224.

Ginns, P. (2005). Meta-analysis of the modality effect. *Learning and Instruction, 15,* 313-331.

Hasler, B. S., kersten, B., & sweller, J. (2007). Learner control, cognitive load and instructional Animation. *Applied cognitive psychology, 21,* 713 – 729.

Hassanabadi, H. R. (1387/2008). Managing split-attention and redundancy in multimedia learning environments: Evidence for dual processing systems in working memory, *Journal of Iranian Psychologists, 5,* 27-41. (in Persion)

Höffler, T. N., & Leutner, D. (2007). Instructional animation versus static pictures: A meta-analysis. *Learning and Instruction, 17,* 722–738.

Jeun, H., Chandler, P., & Sweller, J. (1997). The role of visual indicators in dual sensory mode instruction. *Eduational psychology, 17,* 329- 343.

Kalyuga, S., Chandler, P., & Sweller, J. (1999). Managing split-attention and redundancy in multimedia instruction. *Applied Cognitive Psychology, 13,* 351-371.

Leahy, w., chandler, P. & sweller, J. (2003) . when auditory presentations should and should not be a component of multimedia instruction. *Applied cognitive psychology , 17,* 401- 418.

Lowe, R. K. (1999). Extracting information from an animation during complex visual learning. *European Journal of Psychology of Education, 14,* 225–244.

Lowe, R. K. (2004). Interrogation of a dynamic visualization during learning. *Learning and Instruction, 14,* 257-274.

Mayer, R. E. (1999). Multimedia aids to problem solving transfer. *International Journal of Educational Research, 31,* 611–623.

Mayer, R. E. (2001). *Multimedia learning*. New York: Cambridge University Press.

Mayer, R. E. (2005). Cognitive theory of multimedia learning. In R. Mayer (Ed.), *Cambridge handbook of multimedia learning* (pp. 31–48). New York: Cambridge University Press.

Mayer, R. E., & Chandler, P. (2001). When learning is just a click away: Does simple user interaction foster deeper understanding of multimedia messages? *Journal of Educational Psychology, 93,* 390–397.

Mayer, R. E., Dow, G. T., & Mayer, S. (2003). Multimedia learning in an interactive self-explaining environment: What works in the design of agent-based microworlds? *Journal of Educational Psychology, 95,* 806–813.

Mayer, R. E., Hegarty, M., Mayer, S., & Campbell, J. (2005). When Static Media Promote Active Learning: Annotated Illustrations Versus Narrated Animations in Multimedia Instruction. *Journal of Experimental Psychology: Applied, 11,* 256-265.

Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. *Journal of Educational Psychology, 90,* 312–320.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist, 38,* 43–52.

Mayer, R. E., Moreno, R., Boire, M., & Vagge, S. (1999). Maximizing constructivist learning from multimedia communications by minimizing cognitive load. *Journal of Educational Psychology, 91,* 638–643.

Moreno, R. (2007). Optimizing learning from animations by minimizing cognitive load: Cognitive and affective consequences of signaling and segmentation methods. *Applied Cognitive Psychology, 21,* 1–17.

Moreno, R., & Mayer, R. E. (1999). Cognitive principles of multimedia learning: The role of modality and contiguity. *Journal of Educational Psychology, 91,* 358–368.

Moreno, R., & Mayer, R. E. (2007). Interactive multimodal learning environments special issue on interactive learning environments: Contemporary issues and trends. *Educational Psychology Review, 19,* 309–326.

Moreno, R., & Valdez, A. (2005). Cognitive load and learning effect of having students organize picture and words in multimedia environments: The role of student interactivity and feedback. *Educational Technology Research and Development, 53,* 35-45.

Mousavi, S., Low, R., & Sweller, J. (1995). Reducing cognitive load by mixing auditory and visual presentation modes. *Journal of Educational Psychology, 87,* 319-334.

Perez, E. C. & White, M. A. (1985). Student evaluation of motivational and learning attributes of microcomputer software. *Journal of Computer-Based Instruction, 12,* 39–43.

Schwan, S., & Riempp, R. (2004). The cognitive benefits of interactive videos: Learning to tie moutical knots. *Learning and Instruction, 14,* 293-305.

Sweller, J. (2004). Instructional design consequences of an analogy between evolution by natural selection and human cognitive architecture. *Instructional Science, 32,* 9–31.

Sweller, J. (2005). Implications of cognitive load theory for multimedia learning. In R. E. Mayer (Ed.), *Cambridge handbook of multimedia learning* (pp. 19–30). New York: Cambridge University Press.

Sweller, J., van Merriënboer, J. J. G., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10,* 251–296.

Tabbers, H.K. (2002). *The modality of text in multimedia instructions: Refining the design guidelines*.Unpublished doctoral dissertation, Open University of the Netherlands, Heerlen.

Tabbers, H. K., Martens, R. L., & van Merriënboer, J. J. G. (2004). Multimedia instructions and cognitive load theory: Effect of modality and cueing. *British Journal of Educational Psychology, 74,* 71-81.

Tversky, B., Morrison, J. B., & Betrancourt, M. (2002). Animation: Can it facilitate? *International Journal of Human-Computer Studies, 57,* 247–262.

Wouters, P., Tabbers , H. K., & Paas, F. (2007). Interactivity in video- based models. *Educational Psychology Review, 19,* 327-342.